Contra Costa County
Flood Control
& Water Conservation District

Verification of the District Standards

Draft November 2, 2009

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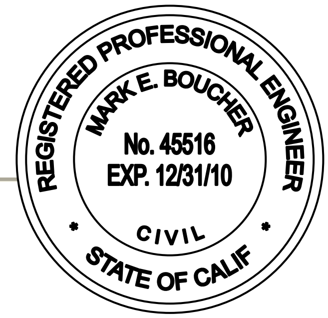
This report was prepared by or under the supervision of the Registered Professional Engineer indicated below:

DRAFT

Mark E. Boucher, PE C 45516 Date:



ACKNOWLEDGEMENTS

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Verification of the District Standards

By: Mark Boucher, Sr. Hydrologist

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Introduction

For many years the Contra Cost Flood Control and Water Conservation District (District) has used several internally developed programs to perform hydrology calculations. These programs were written in FORTRAN and include HYDRO6 (for hydrographs) and HYDRO2 for complex watershed models including multiple watersheds and detention basins. County Counsel has direct staff to not distribute the programs to the public for liability reasons. Hence, anyone wanting a hydrograph for use in a flood study must request the hydrograph from staff.

Currently, District staff is working to replace these programs with more up to date software. This effort to transition to public domain software for the District models requires confirmation of the source of many of the District standards that were coded into the legacy programs. The District intends to use the public domain U.S. Army Corps of Engineers HEC-HMS[1] program (HMS) for future hydrology work. The standards we need to verify include the rainfall distribution curves, the "S"-curve used for the unit hydrograph method, the lag equation, watershed n-values, infiltration rates, and methods used in measuring or calculating specific parameters for the hydrology calculations. This report documents our research to verify the source of the standards. Once verified and documented, we can confidently move forward and produce guidance on how to perform our standard method for hydrology in public domain software thus expanding our and the public's ability to produce hydrographs and hydrologic models that meet our standards.

Rainfall Distribution Curves

The rainfall distribution curves (rainfall curves) are essential for duplicating the District's HYDRO6 model results in HMS. In fact, we have produced hydrographs in HMS that match almost exactly the HYDRO6 results. We want to solidify our confidence in the HMS inputs so that we can confidently move forward in our software transition.

Current Standard Sources

We have found District standards for rainfall curves in two places. The rainfall curves are hardcoded into the HYDRO6 FORTRAN code (see Table 1) and they are published in training material (Figure 1), some copies/version of which are stamped "preliminary". The rainfall curves are from several sources. Personal notes on the training material and recollection from staff that participated in in-house training on the District method indicate standards rainfall curves come from several other standards and sources. Those noted in the class notes are included in Table 1

[1] Software can be downloaded for free from http://www.hec.usace.army.mil/soflware/

Table 1 - Rainfall Distribution Curves from HYDRO6 FORTRAN Code Subroutine with Assumed Source

<table>
<tr><td colspan="2">Values are in 10ths of percent.</td></tr>
<tr><th>RAINFALL CURVE NAME</th><th>ASSUMED SOURCE BASED ON CLASS NOTES.</th></tr>
<tr><td>3-Hour Distribution (15-minute intervals)</td><td>U.S. Army Corps of Engineers</td></tr>
<tr><td colspan="2">DATA KD3 / 30, 20, 50, 28, 88,102, 55, 70,105,110,277, 65/</td></tr>
<tr><td>6-Hour Rainfall Distribution (15-minute intervals)</td><td>Natural Resource Conservation Service</td></tr>
<tr><td colspan="2">DATA KD6 / 21, 25, 38, 45, 60, 30, 23, 25, 48, 43, 26, 25, 22, 25,
1 50, 79,190, 63, 40, 30, 25, 24, 22, 21/</td></tr>
<tr><td>9-Hour Rainfall Distribution (15-minute intervals)</td><td>Source Unknown</td></tr>
<tr><td colspan="2">DATA KD9 / 10, 20, 20, 20, 30, 20, 20, 30, 40, 30, 20, 20, 20, 20,
1 10, 20, 20, 20, 20, 30, 30, 30, 30, 40, 40, 50, 70, 60,
2 50, 40, 30, 20, 20, 20, 20, 10/</td></tr>
<tr><td>12-Hour Rainfall Distribution (15-min. intervals)</td><td>District Developed</td></tr>
<tr><td colspan="2">DATA KD12/ 9, 9, 10, 10, 11, 11, 11, 12, 12, 12, 13, 15, 16, 16,
1 17, 17, 19, 20, 23, 30, 32, 41, 49,146, 61, 36, 31, 28,
2 26, 21, 20, 18, 17, 17, 16, 16, 13, 12, 12, 12, 12, 11,
3 11, 11, 10, 10, 9, 9/</td></tr>
<tr><td>24-Hour Rainfall Distribution (30-min. intervals)</td><td>Natural Resource Conservation Service</td></tr>
<tr><td colspan="2">DATA KD24/ 9, 9, 10, 10, 10, 11, 11, 12, 13, 14, 15, 17, 19, 20,
1 21, 22, 28, 35, 50,151, 66, 41, 31, 30, 26, 24, 21, 19,
2 18, 17, 17, 16, 15, 14, 14, 13, 13, 12, 12, 12, 11, 11,
3 11, 11, 10, 10, 9, 9/</td></tr>
<tr><td>36-Hour Rainfall Distribution (30-min. intervals)</td><td>Source Unknown</td></tr>
<tr><td colspan="2">DATA KD36/ 11, 13, 14, 15, 15, 18, 20, 22, 25, 34, 46,124, 62, 38,
1 30, 24, 22, 20, 16, 15, 15, 14, 13, 11, 3, 3, 4, 4,
2 4, 4, 4, 4, 5, 5, 5, 6, 7, 7, 8, 8, 10, 13,
3 18, 55, 24, 15, 11, 11, 9, 9, 8, 7, 7, 6, 6, 6,
4 5, 5, 5, 5, 5, 4, 4, 4, 4, 4, 4, 4, 4, 4,
5 3, 3/</td></tr>
<tr><td>48-Hour Rainfall Distribution (30-min. intervals)</td><td>Source Unknown</td></tr>
<tr><td colspan="2">DATA KD48/ 7, 7, 7, 7, 8, 8, 8, 9, 9, 9, 10, 11, 12, 12,
1 13, 13, 14, 15, 17, 22, 24, 31, 37,109, 45, 27, 23, 21,
2 19, 16, 15, 13, 13, 13, 12, 12, 10, 9, 9, 9, 9, 8,
3 8, 8, 7, 7, 7, 7, 3, 3, 4, 4, 4, 4, 4, 5,
4 5, 5, 6, 7, 8, 8, 11, 29, 14, 10, 8, 7, 6, 6,
5 5, 5, 5, 5, 5, 4, 4, 4, 4, 4, 4, 4, 4, 4,
6 3, 3, 3, 3, 3, 3, 3, 3, 2, 2, 2, 2/</td></tr>
<tr><td>96-Hour Rainfall Distribution (2 hour intervals)</td><td>U.S. Army Corps of Engineers</td></tr>
<tr><td colspan="2">DATA KD96/ 0, 1, 7, 16, 14, 36, 56, 41, 20, 6, 4, 0, 1, 2,
1 0, 0, 0, 0, 0, 11, 4, 47, 30, 38, 24, 36, 50, 44,
2 44, 44, 39, 47,137, 38, 46, 44, 24, 16, 8, 0, 2, 12,
3 11, 0, 0, 0, 0, 0/</td></tr>
</table>

TABLE 1

RAINFALL DISTRIBUTION COEFFICIENTS FOR VARIOUS DESIGN STORMS

(IN %)

CONTRA COSTA COUNTY FLOOD CONTROL
AND WATER CONSERVATION DISTRICT

DURATION	3-HR from COE	6-HR from SCS	12-HR from [illegible]	24-HR from SCS	4-DAY from COE
INTERVAL	15-MIN	15-MIN	15-MIN	30-MIN	2-HR
1	3.0	2.1	.9	1.0	.0
2	2.0	2.5	.9	1.0	.1
3	5.0	3.8	1.0	1.5	.7
4	2.8	4.5	1.0	1.5	1.6
5	8.8	6.0	1.1	1.6	1.4
6	10.2	3.0	1.1	1.6	3.6
7	5.5	2.3	1.1	1.6	5.6
8	7.0	2.5	1.2	1.8	4.1
9	10.5	4.8	1.2	1.9	2.0
10	11.0	4.3	1.2	2.1	.6
11	27.7	2.6	1.3	2.4	.4
12	6.5	2.5	1.5	2.6	.0
13		2.2	1.6	3.1	.1
14	100.0	2.5	1.6	3.1	.2
15		5.0	1.7	4.2	.0
16		7.9	1.7	11.5	.0
17		19.0	1.9	5.5	.0
18		6.3	2.0	4.0	.0
19		4.0	2.3	3.0	.0
20		3.0	3.0	2.7	1.1
21		2.5	3.2	2.4	.4
22	3hr storm	2.4	4.1	2.3	4.7
23	used for	2.2	4.9	2.1	3.0
24		2.1	14.6	1.9	3.6
25	all hydraulic		6.1	1.9	2.4
26	structure		3.6	1.8	3.6
27			3.1	1.8	5.0
28	design		2.8	1.7	4.4
29	(Political		2.6	1.7	4.4
30	decision)		2.1	1.6	4.4
31			2.0	1.6	3.3
32			1.8	1.5	4.7
33	Alameda Co		1.7	1.5	13.7
34	uses 24hr		1.7	1.5	3.6
35	duration		1.6	1.4	4.6
36			1.6	1.4	4.4
37	Sacramento		1.3	1.3	3.4
38			1.2	1.3	1.5
39	Sonoma		1.2	1.2	.9
40	used 6hr		1.2	1.2	.0
41	duration		1.2	1.2	.2
42			1.1	1.2	1.2
43			1.1	1.2	1.1
44			1.1	1.2	.0
45			1.0	1.1	.0
46			1.0	1.1	.0
47			.9	1.1	.0
48			.9	1.1	.0

Figure 1 – Rainfall Distribution Curve from Training Materials with Personal Notes

The District applied the curves in Table 1 in several HMS models and compared the hydrograph results with HYDRO6 calculations. During this comparison, we found that the 24-hour storm hydrograph calculated in HMS did not match that produced by HYDRO6 while all other storms did. The key to making the HMS model match the HYDRO6 model was the use of the HMS Soil Moisture Accounting loss method in the HMS model. We searched for the origin of each of the curves and documented the results in the following paragraphs.

3-Hour Rainfall Distribution Curve

We contacted the US Army Corps of Engineers (Corps) to verify the source of the 3-hour rainfall distribution curve. They provided a PDF[2] from scanned copy of the "Standard Project Criteria for General and local Storms, Sacramento-San Joaquin Valley", Corps Sacramento District, California, dated April 1971. Page 90 of that PDF has a 3-hour rainfall distribution on it in its Figure C, which very closely matches the 3-hour rainfall distribution the District uses as a standard. This Figure C was copied graphically and overlaid by a chart for comparison in Figure 2. This comparison verifies that this is the source of the 3-hour storm rainfall distribution curve.

On page 3 of an August 1977 report by the District entitled, "Hydrology Report, San Ramon Watershed", the following is written: "The distribution of a 3-hour storm developed by the Corps of Engineers was adopted by the District." The distribution coefficients in Table 3 of that report match those of the 3-hour rainfall curve in the HYRDO6 FORTRAN code and draft standard. This verifies the adoption of the 3-hour rainfall curve by the District.

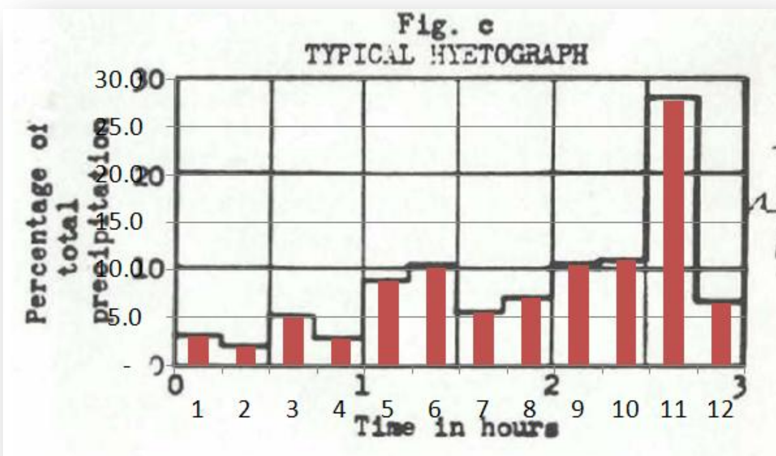

Figure 2 – 3-hour Hour Rainfall Distribution Curve
Original Source Comparison

6-Hour Rainfall Distribution Curve

We contacted the Natural Resource Conservation Service (NRCS) Davis office to verify the source of the 6-hour rainfall curve. They provided a data file with the 6-hour storm in it. That 6-hour rainfall curve is included in Appendix C. A comparison with and subsequent communication with Mr. Greg Norris of the NRCS in Davis, CA showed that the 6-hour curve in HYDRO6 and the District training material did not match any 6-hour curve used by the NRCS. The NRCS said that the 6-hour rainfall curve could be found

[2] Short for Portable Document Format, a file format developed by Adobe Systems.

in their Technical Release 60 (TR-60). We located that document and confirmed that the rainfall curve they provided came from that publication. This can be seen in Figure 3 that has plots the District's 6-hour curve against the TR-60 6-hour curve and the curve the NRCS provided against the same.

On page 3 of the August 1977 by the District report entitled, "Hydrology Report, San Ramon Watershed", the following is written: "The distribution of a 6-hour storm developed by the Soil Conservation District was modified by the District to contain the Soil Conservation District 3-hour flood peak. Both the 3-hour and 6-hour distribution coefficients are presented in Table 3." The distribution coefficients in Table 3 of that report match those of the 6-hour rainfall curve in the HYRDO6 FORTRAN code and draft standard. This verifies the adoption of the 6-hour rainfall curve by the District. The Districts final 6-hour rainfall curve is plotted in Figure 4.

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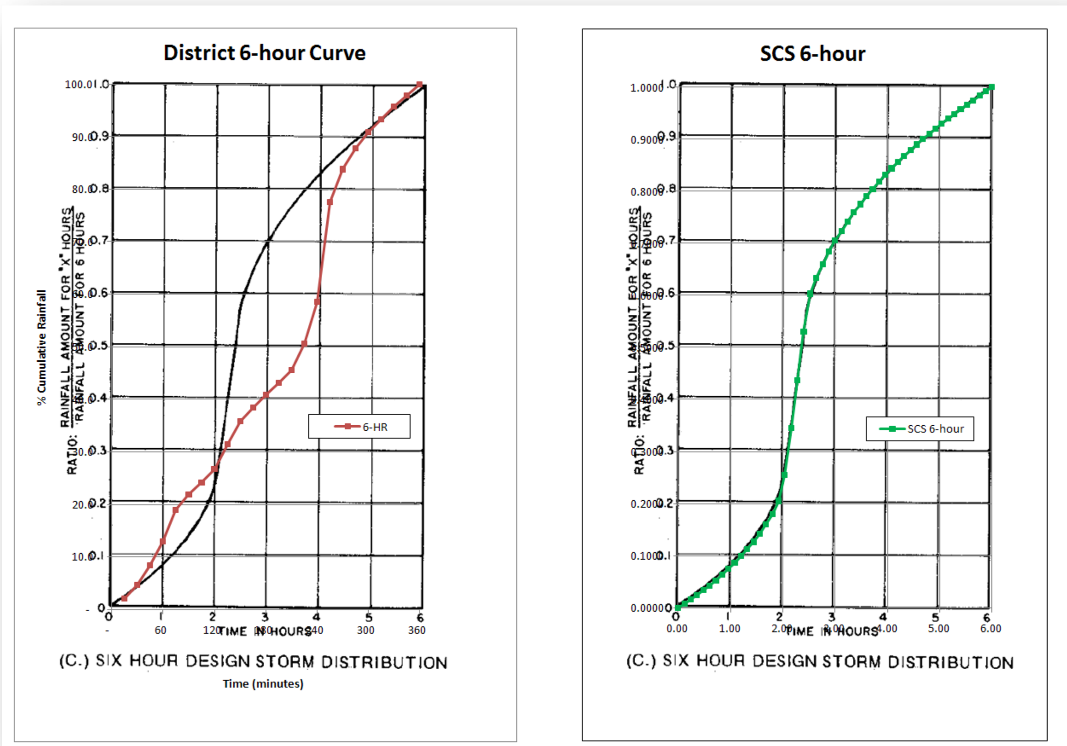

Figure 3 – 6-hour Hour Rainfall Distribution Curve Compared to TR-60 Standard

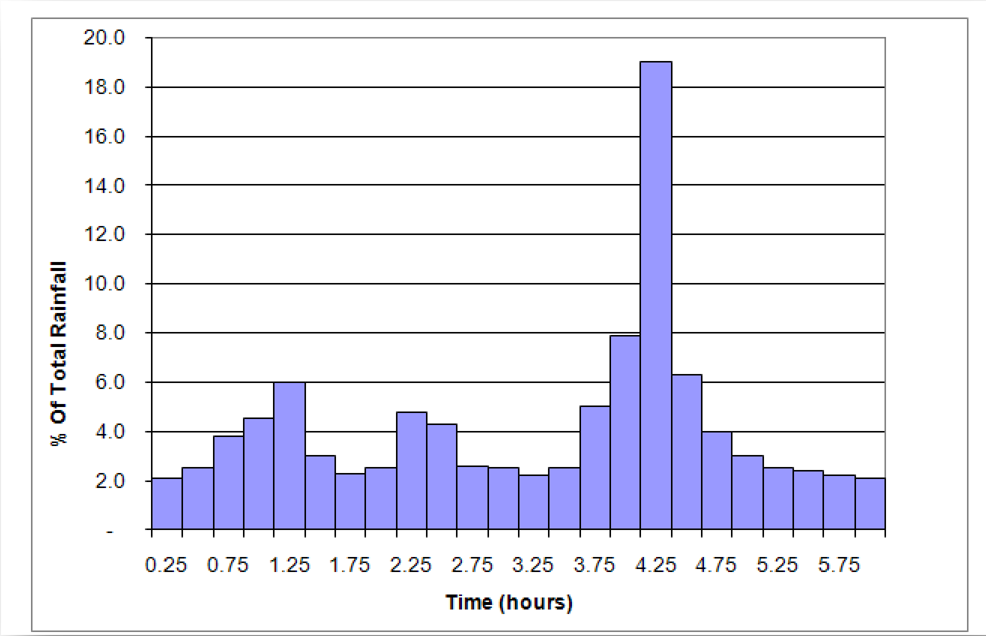

Figure 4 – Final 6-hour Hour Rainfall Distribution Curve

24-hour Rainfall Distribution Curve

We researched the District training material that contained the 24-hour rainfall distribution curve and found it was different from the one we found in the HYDRO6 FORTRAN code. We contacted the NRCS Davis office and received back several 24-hour curves SCS[3] Standard Rainfall Distributions Curves, apparently revised in June 1985. These included the following 24 Hour Standard Rainfall Distribution curves: Type I, Type IA, Type II, and Type III. The raw data provided by the NRCS is included in Appendix C.

These 6-minute interval cumulative curves were converted to cumulative 1-hour curves for comparison with the 24-hour storm distribution curves from the District's FORTRAN code and Standards. Figure 5 presents the cumulative rainfall curves from the District and the Type I and Type IA curves from the SCS plotted together. The District curve from the standards table matches almost perfectly with the Type IA SCS curve. The District curve from the FORTRAN code closely matches to TYPE I SCS curve but is different. The 24-hour curves are also compared in Table 2.

[3] SCS = Soil Conservation Service. The SCS is now the NRCS.

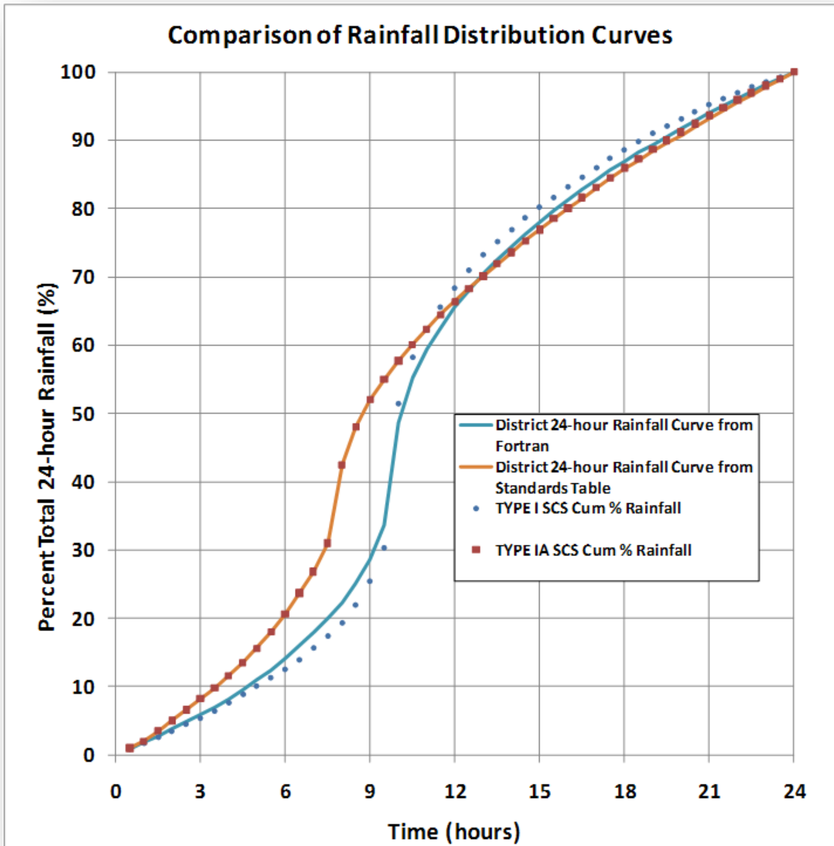

Figure 5 - 24-Hour Rainfall Distribution Curve Comparison

Table 2 - Comparison of 24-hour Rainfall Distribution Curves

	FCDF	FCDS	SCSI	SCSIA	Difference FCDF – SCSI	Difference FCDS – SCSIA
	District HYDRO6 FORTRAN	District Draft Standard	SCS Type I Storm	SCS Type IA Storm		
Duration	24-HR	24-HR	24-HR	24-HR		
Interval	30-MIN	30-MIN	30-MIN	30-MIN		
1	0.90	1.00	0.87	1.00	0.03	0.00
2	0.90	1.00	0.87	1.00	0.03	0.00
3	1.00	1.50	0.88	1.50	0.12	0.00
4	1.00	1.50	0.88	1.50	0.12	0.00
5	1.00	1.60	0.92	1.60	0.08	0.00
6	1.10	1.60	0.98	1.60	0.12	0.00
7	1.10	1.60	1.07	1.60	0.03	0.00
8	1.20	1.80	1.13	1.80	0.07	0.00
9	1.30	1.90	1.18	1.90	0.12	0.00
10	1.40	2.10	1.22	2.10	0.18	0.00
11	1.50	2.40	1.23	2.40	0.27	0.00
12	1.70	2.60	1.27	2.60	0.43	0.00
13	1.90	3.10	1.41	3.10	0.49	0.00
14	2.00	3.10	1.69	3.10	0.31	0.00
15	2.10	4.20	1.86	4.20	0.24	0.00
16	2.20	11.50	1.94	11.50	0.26	0.00
17	2.80	5.50	2.50	5.50	0.30	0.00
18	3.50	4.00	3.50	4.00	0.00	0.00
19	5.00	3.00	4.90	3.00	0.10	0.00
20	15.10	2.70	21.20	2.70	-6.10	0.00
21	6.60	2.40	6.80	2.40	-0.20	0.00
22	4.10	2.30	4.00	2.30	0.10	0.00
23	3.10	2.10	3.25	2.10	-0.15	0.00
24	3.00	1.90	2.85	1.90	0.15	0.00
25	2.60	1.90	2.52	1.90	0.08	0.00
26	2.40	1.80	2.28	1.80	0.12	0.00
27	2.10	1.80	2.03	1.80	0.07	0.00
28	1.90	1.70	1.77	1.70	0.13	0.00
29	1.80	1.70	1.62	1.68	0.18	0.02
30	1.70	1.60	1.58	1.64	0.12	-0.04
31	1.70	1.60	1.53	1.61	0.17	-0.01
32	1.60	1.50	1.47	1.57	0.13	-0.07
33	1.50	1.50	1.42	1.53	0.08	-0.03
34	1.40	1.50	1.38	1.49	0.02	0.01
35	1.40	1.40	1.33	1.45	0.07	-0.05
36	1.30	1.40	1.27	1.42	0.03	-0.02
37	1.30	1.30	1.22	1.38	0.08	-0.08
38	1.20	1.30	1.18	1.34	0.02	-0.04
39	1.20	1.20	1.12	1.30	0.08	-0.10
40	1.20	1.20	1.08	1.26	0.12	-0.06
41	1.20	1.10	1.03	1.23	0.17	-0.03
42	1.20	1.10	0.97	1.19	0.23	0.01
43	1.20	1.10	0.93	1.15	0.27	0.05
44	1.20	1.10	0.87	1.11	0.33	0.09
45	1.10	1.00	0.83	1.07	0.27	0.03
46	1.10	1.00	0.77	1.04	0.33	0.07
47	1.10	0.90	0.73	1.00	0.37	0.10
48	1.10	0.90	0.67	0.96	0.43	0.14

Two more plots, Figure 6 and Figure 7, compare the half-hour incremental rainfall distributions from the Type I and Type IA SCS rainfall distribution curves with the District's two curves that best match them. From the comparison, it appears that the District Standards Curve was taken directly from the SCS Type IA curve. However, the District curve from the FORTRAN code is slightly different from the SCS Type I curve; enough so to consider that the SCS curve has either changed since the FORTRAN code was originally written, had been incorrectly taken off an old SCS graphic (prior to electronic files), or was not intended to match the SCS curves. We do not understand why the District curve in the Standard does not match that in the FORTRAN code even though the class notes indicate that is the source, or why the FORTRAN code curve does not match the SCS standard.

In a paper entitled "Conservative Design Rainfall Distribution"[4], James C.Y. Guo, Professor, Civil Engineering, U. of Colorado at Denver, demonstrates how the rainfall distribution curve can be derived. This paper concludes that the more conservative rainfall distribution curve is one that "combine(s) the low and high enveloping curves with a sharp rise through the rainfall center." This is illustrated in Figure 8 where the data points represent the "envelope" and the curve represents a chosen conservative distribution curve. If we were to choose the conservative approach, would choose the Type I curve because it follows a wider "envelope" and has a sharper rise through the rainfall center.

The HYDRO6 FORTRAN code curve is the different from the SCS Curves. However, when comparing modeling runs using these 24-hour rainfall distribution curves we see that the Type I curve coincides best with the HYDRO6 results. This is illustrated in Figure 9.

NRCS Standards

The NRCS publication "Urban Hydrology for Small Watersheds" (a.k.a. Technical Release 55 or TR-55) contains Appendix B entitled "Synthetic Rainfall Distributions and Rainfall Data Sources". This appendix contains a plot of the Type I, Type IA, Type II and Type III rainfall distribution curves (See Figure 10) as well as a map of the United States indicating where the different types of rainfall distributions should be applied. Figure 11 is a copy of that map with a blow up of the Bay Area inset. This figure indicates that most of the Bay Area should use the Type I rainfall distribution while the North West portion of the county would use the Type IA portion. This is an indicator that they Type I distribution was used as a standard. It could also indicate that the distribution curve used in the FORTRAN code was a blending of the two curves.

Conclusion, Recommendation and Implications for the 24-hour rainfall curve.

The draft District standards indicate that the District adopted the SCS curve 24-hour rainfall curve. In addition, the SCS Type I 24-hour rainfall distribution curve produces a peak flow that best coincides with the HYDRO6 peak flow. It is also more conservative than the Type IA curve. We can only conclude that the intent was to adopt the SCS Type I 24-hour rainfall distribution as the District standard. With that, we recommend that the SCS Type I 24-hour rainfall distribution curve, as supplied by the NRCS, be adopted and used as the District Standard and future modeling of design storms in the District.

The implication of adopting this standard is that the 24-hour design storm will have a higher peak flow than HYDRO6 would produce. Facilities originally designed based on the 24-hour storm may be found to be under designed. Many of the designs that the District performs regularly use the 3-, 6-, and 12-hour storms since they produce higher peak flows. The 24-hour design storm is rarely used (correct?).

[4] Guo, J, C.Y. and Hargadin, K (2008) "Conservative Design Rainfall Distribution", submitted to J. of Hydrologic Engineering, April (http://carbon.cudenver.edu/~jguo/PaperWeb/RainCurve.pdf)

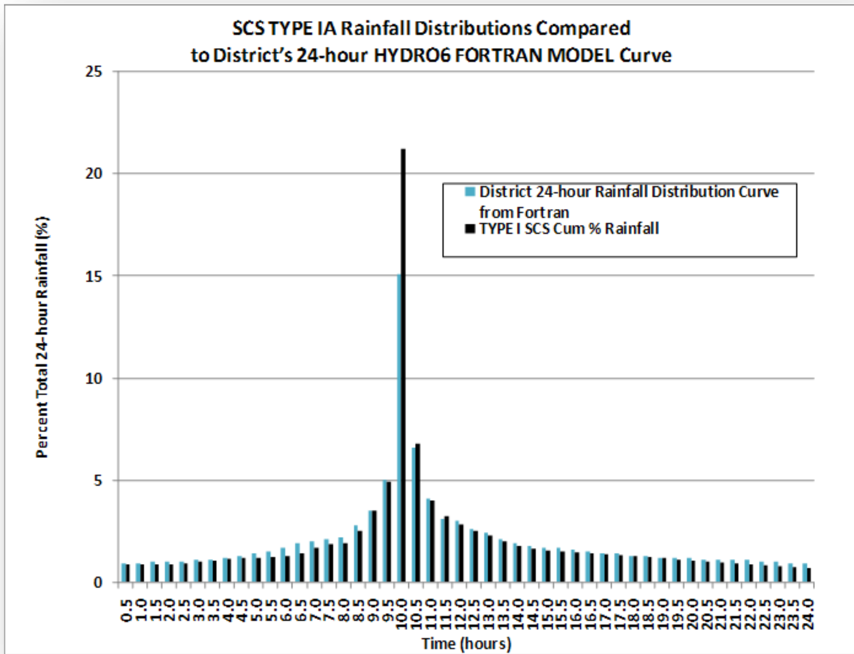

Figure 6 - District FORTRAN Code 24-hour Rainfall Distribution Curve and the SCS Type I curve.

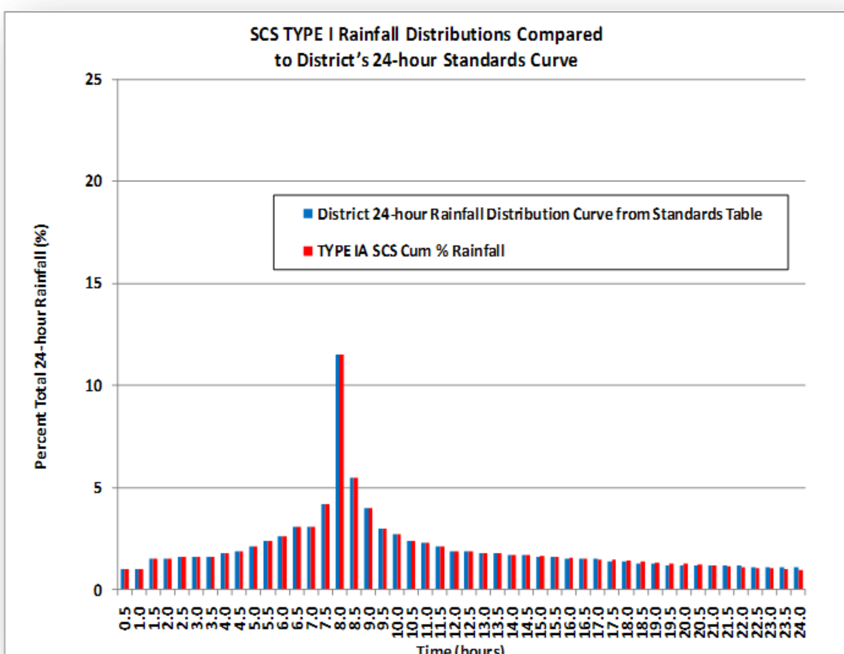

Figure 7 - District Standards 24-hour Rainfall Distribution Curve and the SCS Type IA curve.

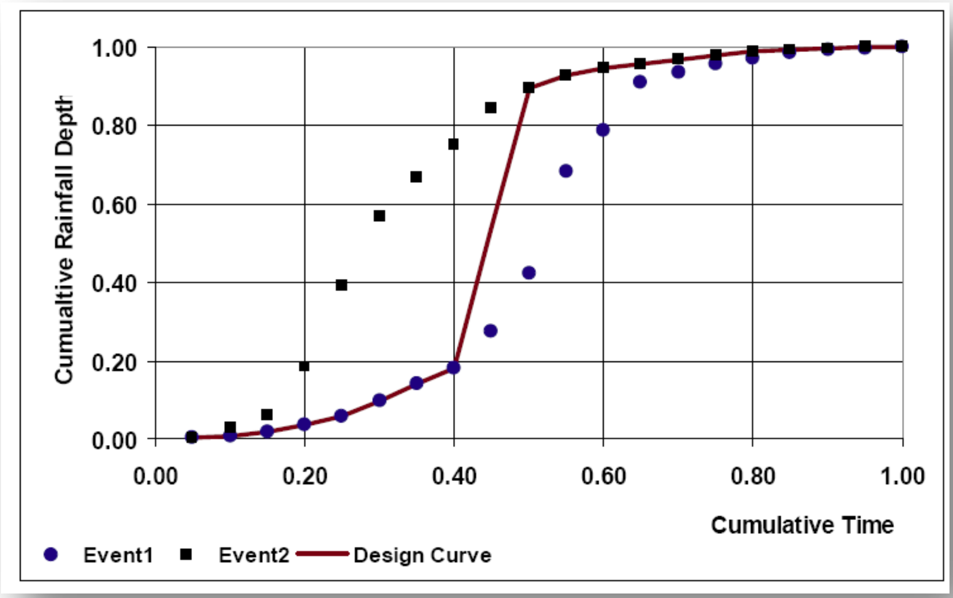

Figure 8 – Figure 2 from "Conservative Design Rainfall Distribution" by Guo

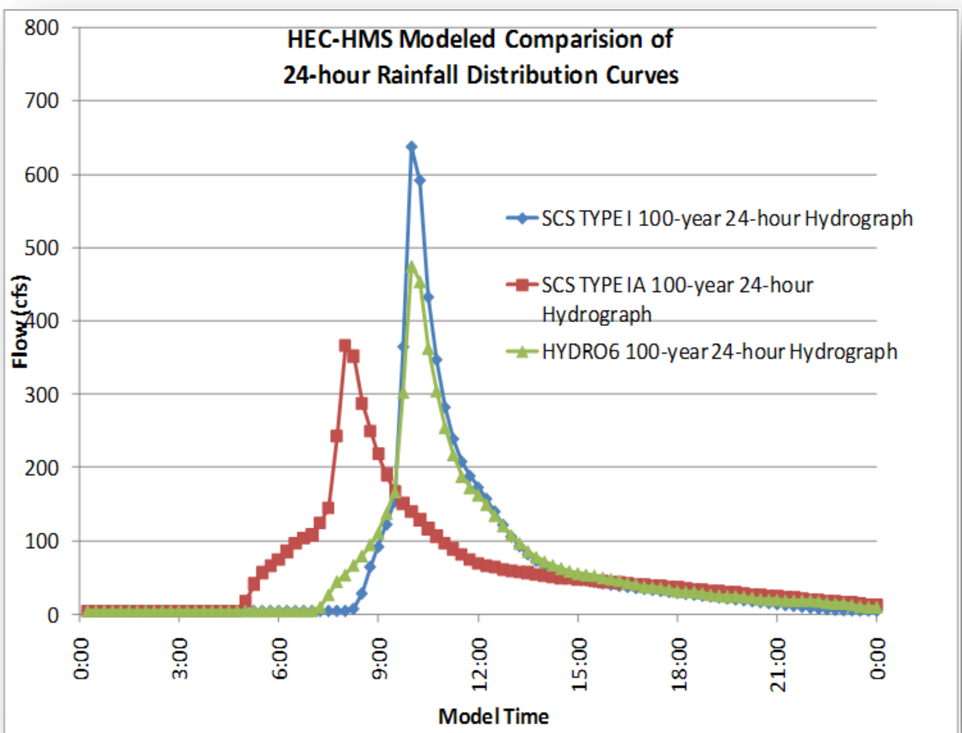

Figure 9 – HEC-HMS Model Comparison of 24-hour Rainfall Distribution Curves

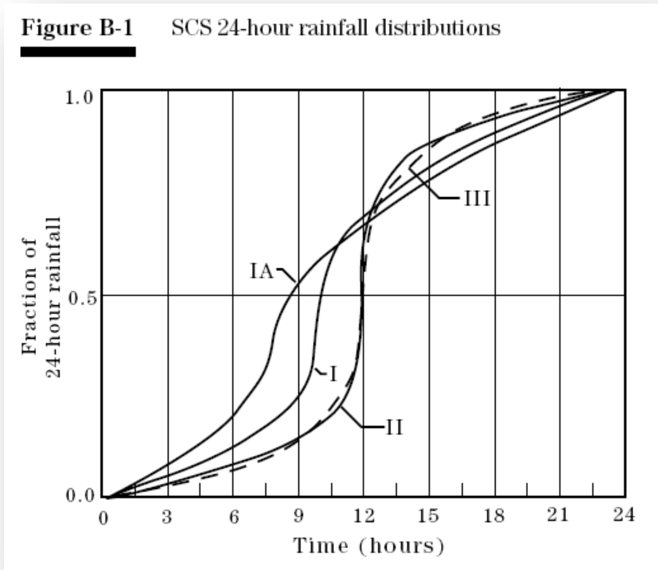

Figure 10 – Figure B-2 from TR-55 with inset blowup of the Bay Area

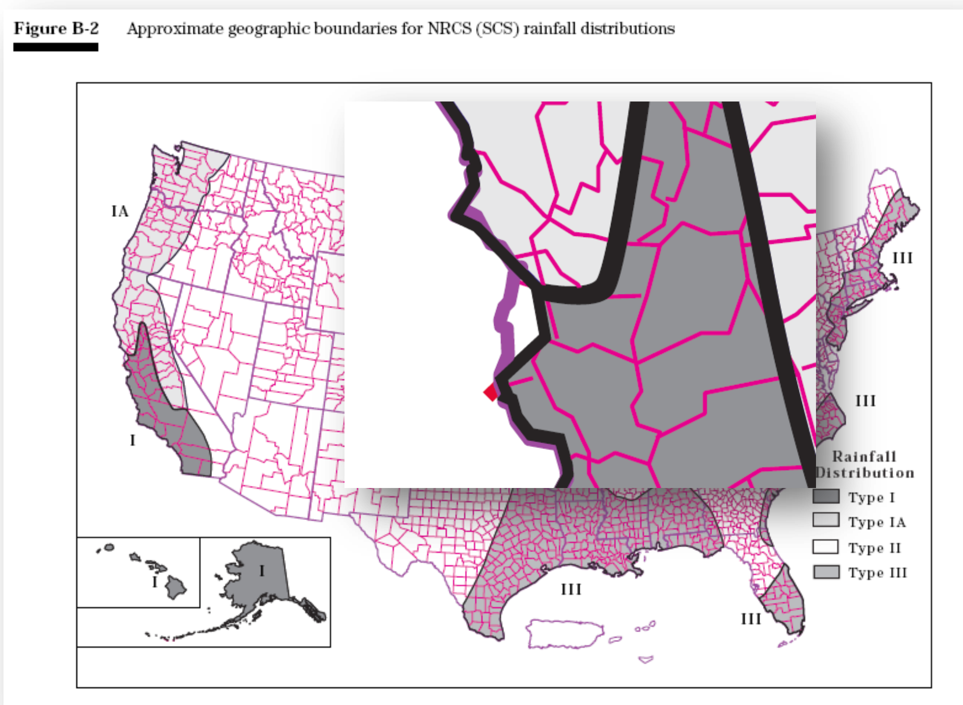

Figure 11 – Figure B-2 from TR-55 with inset of the Bay Area

Further Potential Investigation for the 24-hour Rainfall Curve

There are further investigative steps that we could undertake to understand the basis and affects of this clarification.

1. Contact Dr. Paul Wu to confirm that the SCS standard had been adopted for the 24-hour design storm. We may find that his intent was to adopt the SCS Type I curve, but that his source has been changed and today's SCS standard is different from the one he adopted. We may otherwise find that he extrapolated the curve off of a nomograph and unintended differences were introduced in the process. A third possibility is that he developed his own 24-hour rainfall distribution curve and the notes in the preliminary standards are in error.
2. Research rainfall records of significant 24-hour events to determine if the Type I rainfall distribution curve does in fact represent the 24-hour rainfall patterns in Contra Costa County. Gau demonstrated in his paper that the area he studied did not produce a clear 24-hour curve. If we were to perform a similar study using local data, we also may not find a clear pattern.

96-hour Rainfall Distribution Curve

The U.S. Army Corps of Engineers Hydrologist recognized the 96-hour storm as possibly being based on the big 1962 "Orinda Filters" storm. The Orinda Filter Plant is a rain gage operated by the East Bay Municipal Engineers.

We reviewed some of the other documents in which we have found standards. In that process we ran across a rainfall pattern that looked very much like the 96-hour rainfall curve. We found a rainfall pattern in the Corps study entitled "Walnut Creek Basin, California – Hydrology" dated January 1971 and Revised January 1972 (1971 Walnut Creek Study). The page is copied in Figure 12. The 96-hour rainfall curve was plotted in Excel and scaled to equal the total rainfall shown in Figure 12. Rainfall pattern from the report was scanned and the Excel plot overlaid on it in Figure 13. The coloration between the two confirms that these are the same storm.

The text of the 1971 Walnut Creek Study discuses the transposition of an October 1962 storm that was centered over an "adjacent basin with meteorological characteristics similar to those of Walnut Creek." Therefore this storm was likely not one based on the Orinda Filter Plant data. The text explains that it was taken from a 72-hour storm pattern transposed from an October 1962 storm from the Coast Ranges south of San Francisco. The rainfall amounts were scaled by the annual precipitation and augmented with additional precipitation to extend the duration to 96 hours and confirm with the Corps Standard Project Flood Criteria Report.

We also found hourly rainfall records for Upper San Leandro Filters in a binder labeled "Storm Events – Selected Hourly Rainfall, Dec '55, Apr' 58 and Others (ELF26-Oct 26)". The "ELF26" gage is the Upper San Leandro Filters rain gage. A plot of this data follows a similar pattern as the 96-hour storm in the District Standard.

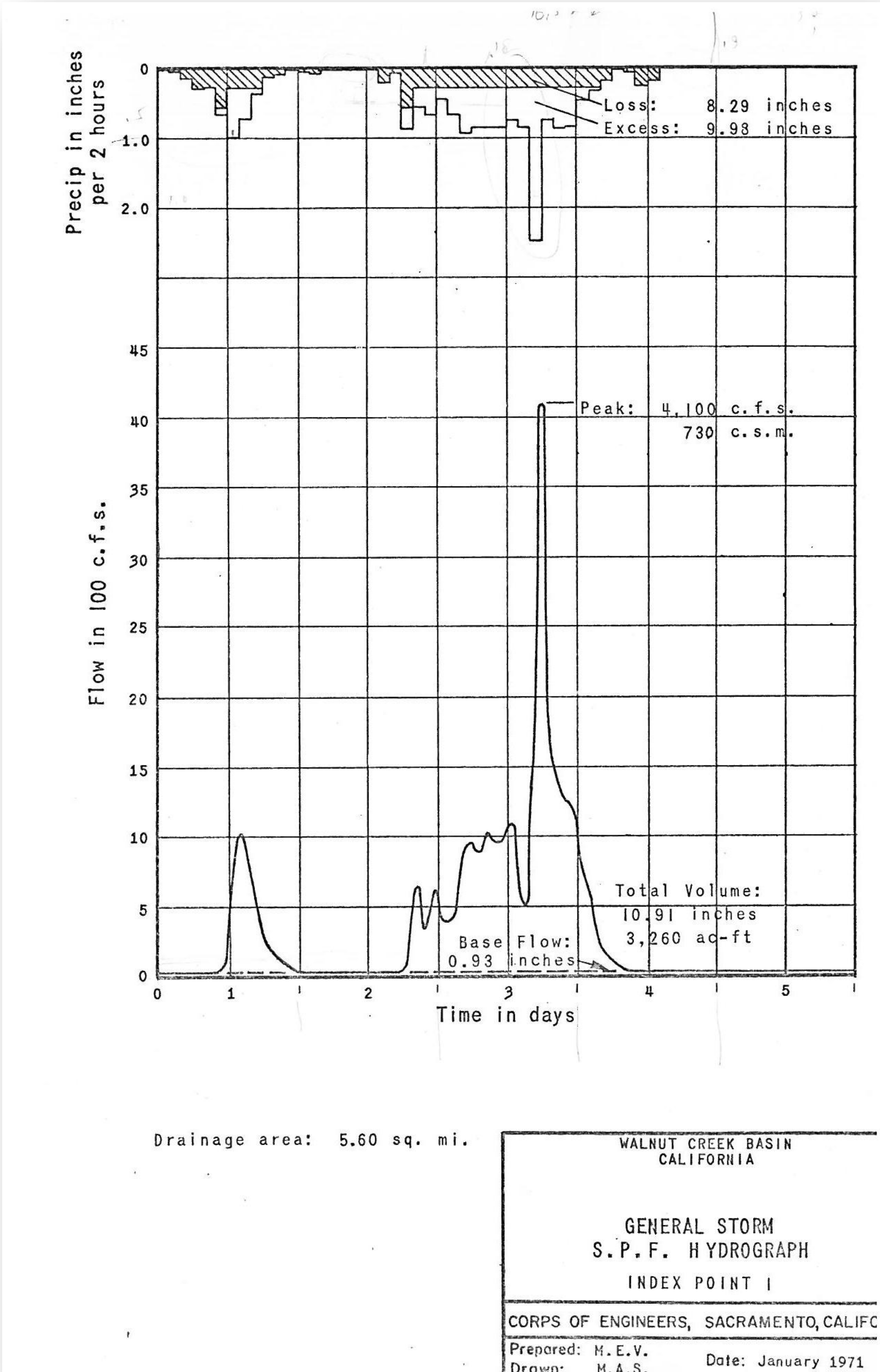

Figure 12 – Copy of Sheet 1 of 4 of Chart 11 from 1971 Walnut Creek Study

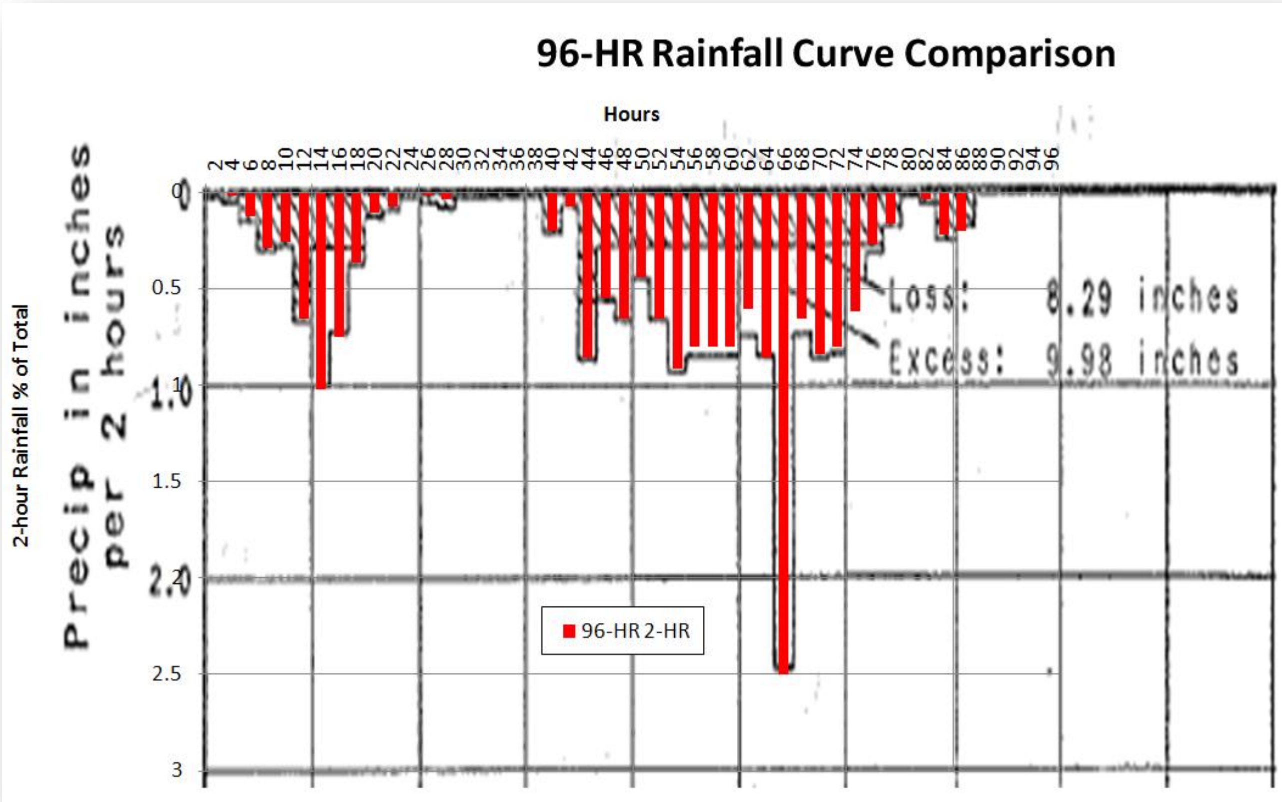

Figure 13 – Plot of 96-hour Rainfall Distribution Overlaid On Precipitation from Sheet 1 of 4 of Chart 11 from 1971 Walnut Creek Study

9-hour, 36-hour, and 48-hour Rainfall Distribution Curves

These three curves are in the HYDRO6 FORTRAN program. However, they are rarely used and are not seen as standard and should not be used unless a situation arises that warrants their use. Figure 14 is a plot of these three curves. The 9-hour curve appears to be like the6-hour curve in that the pattern is of a few smaller burst or rain followed by a larger one. The 36-hour and 48-hour curves may be composites of the SCS storms scaled to create those events. At some later time, it may be worth researching deeper to determine the origin and usefulness of these curves. At this time, we will not research these three curves further since they are very rarely used.

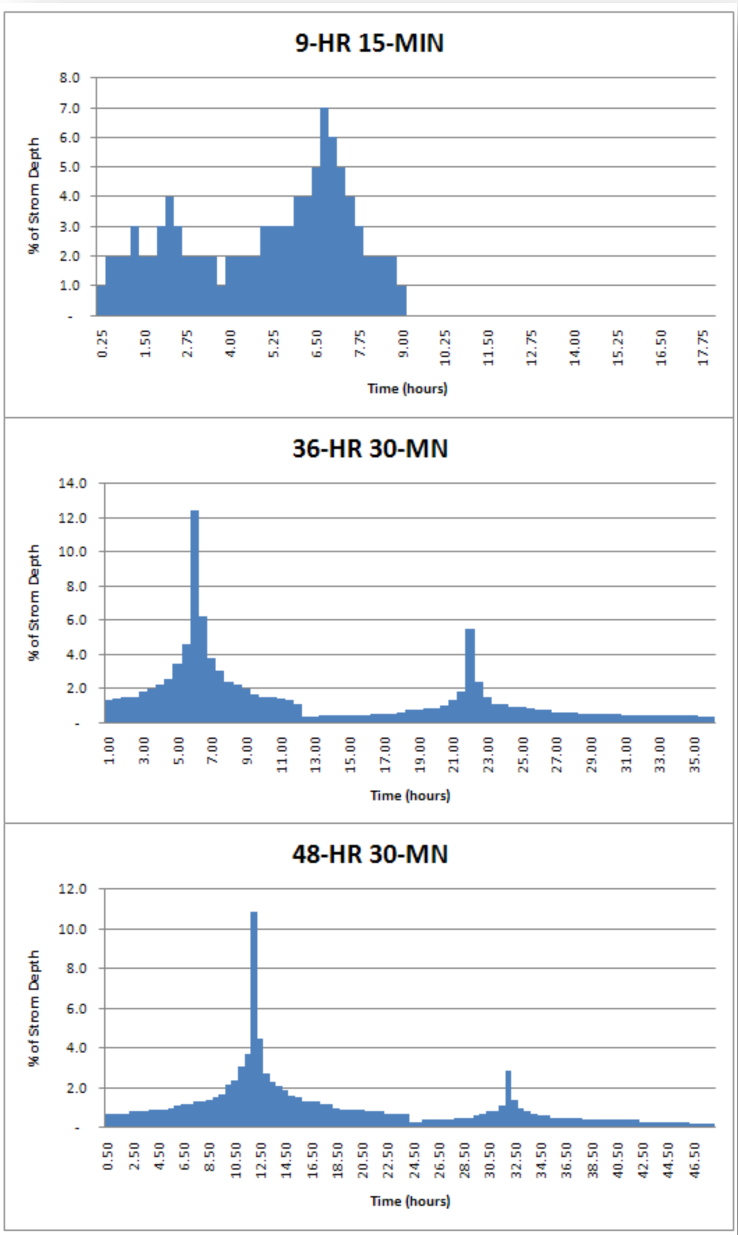

Figure 14 – Plot of 9-hour, 36-hour, 48-hour Rainfall Distribution Curves

District Standard Rainfall Distribution Curves

The final standard rainfall distribution curves for the District are presented inTable 3. These are the now verified rainfall distribution curves the District has been and will use for developing design hydrographs and their respective design storm peak flows.

The verified sources of these curves are listed below:

- 3-hour U.S. Army Corps of Engineers
    - "Standard Project Criteria for General and local Storms, Sacramento-San Joaquin Valley", Corps Sacramento District, California Dated April 1971.
    - "Hydrology Report, San Ramon Watershed", Contra Costa County Flood Control and Water Conservation District, August 1977

- 6-hour Modified SCS rainfall distribution to contain Corps 3-hour storm distribution
    - "Hydrology Report, San Ramon Watershed", Contra Costa County Flood Control and Water Conservation District, August 1977

- 9-hour Source Unknown- (assumed District Developed —This curve is not a "public")

- 12-hour District developed

- 24-hour Natural Resource Conservation District Type I rainfall distribution
    - "Urban Hydrology for Small Watersheds" (TR-55) Appendix B entitled

- 36-hour Source Unknown- (assumed District Developed —This curve is not a "public")

- 48-hour Source Unknown- (assumed District Developed —This curve is not a "public")

- 96-hour U.S. Army Corps of Engineers
    - 72-hour storm pattern transposed from an October 1962 storm from the Coast Ranges south of San Francisco and scaling the rainfall amounts by the annual precipitation and augmenting it with additional precipitation to extend the duration to 96 hours. "Walnut Creek Basin, California — Hydrology" dated January 1971 and Revised January 1972.

Table 3 – District Standard Rainfall Distribution Curves in Percentage (%) of Storm Total

Duration Interval	3-HR 15-MIN	6-HR 15-MIN	9-HR[5] 15-MIN	12-HR 15-MIN	24-HR 30-MIN	36-HR[5] 30-MIN	48-HR[5] 30-MIN	96-HR 2-HR
1	3.0	2.1	1.0	0.9	0.87	1.1	0.7	-
2	2.0	2.5	2.0	0.9	0.87	1.3	0.7	0.1
3	5.0	3.8	2.0	1.0	0.88	1.4	0.7	0.7
4	2.8	4.5	2.0	1.0	0.88	1.5	0.7	1.6
5	8.8	6.0	3.0	1.1	0.92	1.5	0.8	1.4
6	10.2	3.0	2.0	1.1	0.98	1.8	0.8	3.6
7	5.5	2.3	2.0	1.1	1.07	2.0	0.8	5.6
8	7.0	2.5	3.0	1.2	1.13	2.2	0.9	4.1
9	10.5	4.8	4.0	1.2	1.18	2.5	0.9	2.0
10	11.0	4.3	3.0	1.2	1.22	3.4	0.9	0.6
11	27.7	2.6	2.0	1.3	1.23	4.6	1.0	0.4
12	6.5	2.5	2.0	1.5	1.27	12.4	1.1	-
13		2.2	2.0	1.6	1.41	6.2	1.2	0.1
14		2.5	2.0	1.6	1.69	3.8	1.2	0.2
15		5.0	1.0	1.7	1.86	3.0	1.3	-
16		7.9	2.0	1.7	1.94	2.4	1.3	-
17		19.0	2.0	1.9	2.50	2.2	1.4	-
18		6.3	2.0	2.0	3.50	2.0	1.5	-
19		4.0	2.0	2.3	4.90	1.6	1.7	-
20		3.0	3.0	3.0	21.20	1.5	2.2	1.1
21		2.5	3.0	3.2	6.80	1.5	2.4	0.4
22		2.4	3.0	4.1	4.00	1.4	3.1	4.7
23		2.2	3.0	4.9	3.25	1.3	3.7	3.0
24		2.1	4.0	14.6	2.85	1.1	10.9	3.6
25			4.0	6.1	2.52	0.3	4.5	2.4
26			5.0	3.6	2.28	0.3	2.7	3.6
27			7.0	3.1	2.03	0.4	2.3	5.0
28			6.0	2.8	1.77	0.4	2.1	4.4
29			5.0	2.6	1.62	0.4	1.9	4.4
30			4.0	2.1	1.58	0.4	1.6	4.4
31			3.0	2.0	1.53	0.4	1.5	3.3
32			2.0	1.8	1.47	0.4	1.3	4.7
33			2.0	1.7	1.42	0.5	1.3	13.7
34			2.0	1.7	1.38	0.5	1.3	3.6
35			2.0	1.6	1.33	0.5	1.2	4.6
36			1.0	1.6	1.27	0.6	1.2	4.4
37				1.3	1.22	0.7	1.0	3.4
38				1.2	1.18	0.7	0.9	1.5
39				1.2	1.12	0.8	0.9	0.9
40				1.2	1.08	0.8	0.9	-
41				1.2	1.03	1.0	0.9	0.2
42				1.1	0.97	1.3	0.8	1.2
43				1.1	0.93	1.8	0.8	1.1
44				1.1	0.87	5.5	0.8	-
45				1.0	0.83	2.4	0.7	-
46				1.0	0.77	1.5	0.7	-
47				0.9	0.73	1.1	0.7	-
48				0.9	0.67	1.1	0.7	-
49						0.9	0.3	
50						0.9	0.3	
51						0.8	0.4	
52						0.7	0.4	
53						0.7	0.4	
54						0.6	0.4	

[5] Do not use the 3-hour, 36-hour, or 48-hour rainfall distribution curves without consulting the FC District.

Duration Interval	3-HR 15-MIN	6-HR 15-MIN	9-HR[5] 15-MIN	12-HR 15-MIN	24-HR 30-MIN	36-HR[5] 30-MIN	48-HR[5] 30-MIN	96-HR 2-HR
55						0.6	0.4	
56						0.6	0.5	
57						0.5	0.5	
58						0.5	0.5	
59						0.5	0.6	
60						0.5	0.7	
61						0.5	0.8	
62						0.4	0.8	
63						0.4	1.1	
64						0.4	2.9	
65						0.4	1.4	
66						0.4	1.0	
67						0.4	0.8	
68						0.4	0.7	
69						0.4	0.6	
70						0.4	0.6	
71						0.3	0.5	
72						0.3	0.5	
73							0.5	
74							0.5	
75							0.5	
76							0.4	
77							0.4	
78							0.4	
79							0.4	
80							0.4	
81							0.4	
82							0.4	
83							0.4	
84							0.4	
85							0.3	
86							0.3	
87							0.3	
88							0.3	
89							0.3	
90							0.3	
91							0.3	
92							0.3	
93							0.2	
94							0.2	
95							0.2	
96							0.2	
Total %	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

S-Curve and Lag Equation

An S-curve is a dimensionless cumulative can be input into HMS as a percent curve and used as "user specified S-curve" in the transform method for a watershed. It is used in conjunction with a lag time to calculate the unit hydrograph, which is the basis for the storm hydrograph.

S-Curve Source

The 1971 Walnut Creek Study contains Chart 7 that is a plot of the Mountain and valley "5" curves used in that report. The previous Sr. Hydrologist stated they chose this Mountain Curve to apply to all of Contra Costa County. We scanned Chart 7 from the report and overlaid an Excel graph of the Mountain curve data from the HYDRO6 FORTRAN code. The overlay can be found in Figure 15.

The HYRDO6 program contained data for an S-curve in 5% increments along the dimensionless time axis (see data in Table 4). Early attempts to duplicate the HYDRO6 results in a spreadsheet were unsuccessful because the numerical values were never exactly the same. We later were told that the HYDRO6 FORTRAN code performed a 4-point parabolic interpolation of the points. The differences between this type of interpolation and a straight-line interpolation was the source of the errors in the spreadsheet calculations. Using 4-point parabolic interpolation, the 5% increments were divided into 1% increments. This 1% increment curve provide excellent agreement between the HYDRO6 and spreadsheet calculations. This 1% S-curve is provided in Table 5 is the District standard for use or the S-curve method in HMS. It is available in digital form from the District Hydrologist.

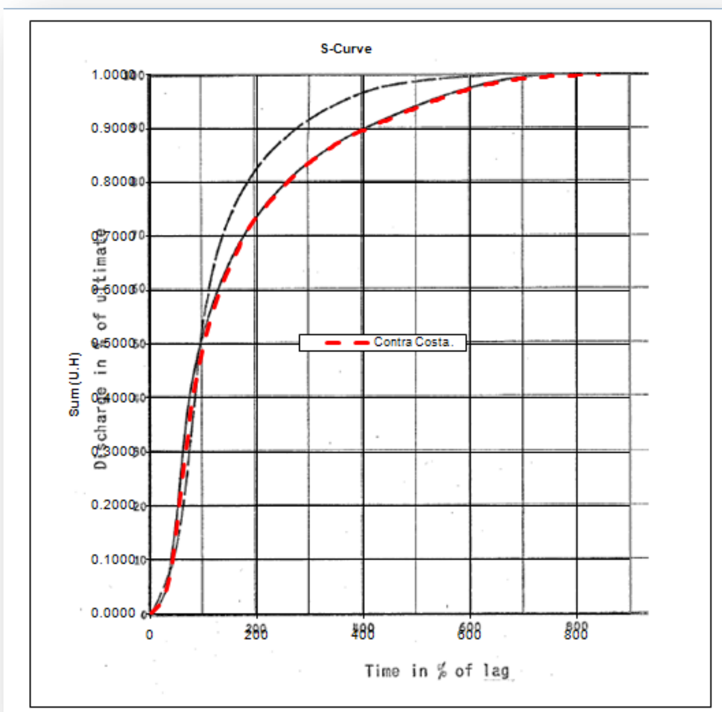

Figure 15 – Plot of the HYDRO6 FORTRAN S-Curve Data over the Corps Mountain S-curve from the 1971 Walnut Creek Study

Table 4 – Mountain S-curve from the HYDRO6 FORTRAN Code

Mountain S-curve – 5% increments along the dimensionless time axis.

```
DATA KMTN/   40,   80,  140,  220,  320,  460,  670,  960,1350,1760,2230,
     1     2650,3030,3380,3700,4000,4280,4540,4780,5000,5200,5380,
     2     5550,5710,5860,6000,6130,6255,6375,6490,6600,6705,6805,
     3     6900,6990,7075,7155,7230,7300,7365,7428,7490,7551,7610,
     4     7668,7725,7781,7835,7888,7940,7991,8040,8088,8135,8181,
     5     8225,8268,8310,8351,8390,8428,8465,8501,8536,8570,8603,
     6     8635,8666,8696,8725,8753,8780,8806,8831,8856,8880,8904,
     7     8928,8951,8974,8997,9020,9042,9064,9086,9108,9130,9151,
     8     9172,9193,9214,9235,9256,9276,9296,9316,9336,9356,9376,
     9     9396,9415,9434,9453,9472,9491,9509,9527,9545,9563,9580,
     1     9597,9614,9631,9647,9663,9679,9694,9709,9724,9738,9752,
     2     9766,9779,9792,9804,9816,9827,9838,9848,9858,9867,9876,
     3     9884,9892,9899,9906,9912,9918,9924,9929,9934,9939,9944,
     4     9948,9952,9956,9960,9964,9967,9970,9973,9976,9979,9981,
     5     9983,9985,9987,9989,9991,9992,9993,9994,9995,9996,9997,
     6     9998,9999,10000,-100/
```

Table 5 – Adopted Mountain S-curve: 1% Time Increments

Mountain S-Curve 1% Time Increments – Part 1											
Spans 2 pages – Read left to right, top to bottom.											
0.0779	0.1560	0.2380	0.3170	0.4000	0.4768	0.5504	0.6256	0.7072	0.8000	0.9040	1.0160
1.1360	1.2640	1.4000	1.5440	1.6960	1.8560	2.0240	2.2000	2.3808	2.5664	2.7616	2.9712
3.2000	3.4432	3.6976	3.9704	4.2688	4.6000	4.9624	5.3512	5.7688	6.2176	6.7000	7.2128
7.7544	8.3296	8.9432	9.6000	10.3130	11.0780	11.8780	12.6910	13.5000	14.2980	15.0970	15.9070
16.7380	17.6000	18.5100	19.4610	20.4270	21.3820	22.3000	23.1780	24.0350	24.8730	25.6940	26.5000
27.2900	28.0630	28.8210	29.5660	30.3000	31.0240	31.7360	32.4360	33.1240	33.8000	34.4620	35.1110
35.7490	36.3780	37.0000	37.6160	38.2240	38.8240	39.4160	40.0000	40.5760	41.1440	41.7040	42.2560
42.8000	43.3360	43.8640	44.3840	44.8960	45.4000	45.8960	46.3840	46.8640	47.3360	47.8000	48.2560
48.7040	49.1440	49.5760	50.0000	50.4160	50.8240	51.2240	51.6160	52.0000	52.3740	52.7390	53.0970
53.4500	53.8000	54.1480	54.4920	54.8320	55.1680	55.5000	55.8280	56.1520	56.4720	56.7880	57.1000
57.4080	57.7120	58.0120	58.3080	58.6000	58.8880	59.1720	59.4520	59.7280	60.0000	60.2670	60.5300
60.7880	61.0450	61.3000	61.5540	61.8060	62.0560	62.3040	62.5500	62.7940	63.0360	63.2760	63.5140
63.7500	63.9840	64.2160	64.4460	64.6740	64.9000	65.1240	65.3460	65.5660	65.7840	66.0000	66.2140
66.4260	66.6360	66.8440	67.0500	67.2540	67.4560	67.6560	67.8540	68.0500	68.2440	68.4360	68.6260
68.8140	69.0000	69.1840	69.3660	69.5460	69.7240	69.9000	70.0740	70.2460	70.4160	70.5840	70.7500
70.9140	71.0760	71.2360	71.3940	71.5500	71.7040	71.8560	72.0060	72.1540	72.3000	72.4440	72.5860
72.7260	72.8640	73.0000	73.1330	73.2650	73.3940	73.5220	73.6500	73.7770	73.9040	74.0300	74.1550
74.2800	74.4050	74.5290	74.6530	74.7770	74.9000	75.0230	75.1460	75.2680	75.3890	75.5100	75.6290
75.7480	75.8660	75.9830	76.1000	76.2170	76.3330	76.4490	76.5650	76.6800	76.7950	76.9090	77.0230
77.1370	77.2500	77.3630	77.4760	77.5880	77.6990	77.8100	77.9190	78.0280	78.1360	78.2430	78.3500
78.4570	78.5630	78.6690	78.7750	78.8800	78.9850	79.0890	79.1930	79.2970	79.4000	79.5030	79.6060
79.7080	79.8090	79.9100	80.0090	80.1080	80.2060	80.3030	80.4000	80.4970	80.5930	80.6890	80.7850
80.8800	80.9750	81.0690	81.1630	81.2570	81.3500	81.4430	81.5360	81.6280	81.7190	81.8100	81.8990
81.9880	82.0760	82.1630	82.2500	82.3370	82.4230	82.5090	82.5950	82.6800	82.7650	82.8490	82.9330
83.0170	83.1000	83.1830	83.2660	83.3480	83.4290	83.5100	83.5890	83.6680	83.7460	83.8230	83.9000
83.9770	84.0530	84.1290	84.2050	84.2800	84.3550	84.4290	84.5030	84.5770	84.6500	84.7230	84.7950
84.8670	84.9390	85.0100	85.0810	85.1510	85.2210	85.2910	85.3600	85.4290	85.4970	85.5650	85.6330
85.7000	85.7670	85.8330	85.8990	85.9650	86.0300	86.0950	86.1590	86.2230	86.2870	86.3500	86.4130
86.4750	86.5370	86.5990	86.6600	86.7210	86.7810	86.8410	86.9010	86.9600	87.0190	87.0770	87.1350
87.1930	87.2500	87.3070	87.3630	87.4190	87.4750	87.5300	87.5850	87.6390	87.6930	87.7470	87.8000
87.8530	87.9050	87.9570	88.0090	88.0600	88.1110	88.1610	88.2110	88.2600	88.3100	88.3600	88.4100
88.4610	88.5110	88.5600	88.6090	88.6570	88.7040	88.7520	88.8000	88.8480	88.8960	88.9440	88.9920
89.0400	89.0880	89.1360	89.1850	89.2330	89.2800	89.3270	89.3730	89.4190	89.4640	89.5100	89.5560
89.6020	89.6480	89.6940	89.7400	89.7860	89.8320	89.8780	89.9240	89.9700	90.0160	90.0620	90.1090
90.1550	90.2000	90.2450	90.2890	90.3320	90.3760	90.4200	90.4640	90.5080	90.5520	90.5960	90.6400
90.6840	90.7280	90.7720	90.8160	90.8600	90.9040	90.9480	90.9920	91.0360	91.0800	91.1240	91.1690
91.2130	91.2570	91.3000	91.3430	91.3850	91.4260	91.4680	91.5100	91.5520	91.5940	91.6360	91.6780
91.7200	91.7620	91.8040	91.8460	91.8880	91.9300	91.9720	92.0140	92.0560	92.0980	92.1400	92.1820
92.2240	92.2660	92.3080	92.3500	92.3920	92.4350	92.4770	92.5190	92.5600	92.6010	92.6410	92.6800
92.7200	92.7600	92.8000	92.8400	92.8800	92.9200	92.9600	93.0000	93.0400	93.0800	93.1200	93.1600
93.2000	93.2400	93.2800	93.3200	93.3600	93.4000	93.4400	93.4800	93.5200	93.5600	93.6000	93.6400

Mountain S-Curve 1% Time Increments (Continued) Part 2											
93.6800	93.7200	93.7600	93.8000	93.8400	93.8810	93.9210	93.9600	93.9990	94.0370	94.0750	94.1120
94.1500	94.1880	94.2260	94.2640	94.3020	94.3400	94.3780	94.4160	94.4540	94.4920	94.5300	94.5680
94.6060	94.6440	94.6820	94.7200	94.7580	94.7970	94.8350	94.8730	94.9100	94.9470	94.9830	95.0190
95.0540	95.0900	95.1260	95.1620	95.1980	95.2340	95.2700	95.3060	95.3420	95.3780	95.4140	95.4500
95.4860	95.5220	95.5590	95.5950	95.6300	95.6650	95.6990	95.7320	95.7660	95.8000	95.8340	95.8680
95.9020	95.9360	95.9700	96.0040	96.0380	96.0720	96.1060	96.1400	96.1740	96.2090	96.2430	96.2770
96.3100	96.3430	96.3750	96.4070	96.4380	96.4700	96.5020	96.5340	96.5660	96.5980	96.6300	96.6620
96.6950	96.7270	96.7590	96.7900	96.8210	96.8510	96.8810	96.9100	96.9400	96.9700	97.0000	97.0300
97.0600	97.0900	97.1200	97.1500	97.1810	97.2110	97.2400	97.2690	97.2970	97.3250	97.3520	97.3800
97.4080	97.4360	97.4640	97.4920	97.5200	97.5480	97.5760	97.6050	97.6330	97.6600	97.6870	97.7130
97.7390	97.7640	97.7900	97.8160	97.8420	97.8690	97.8950	97.9200	97.9450	97.9690	97.9930	98.0160
98.0400	98.0640	98.0890	98.1130	98.1370	98.1600	98.1830	98.2050	98.2270	98.2480	98.2700	98.2920
98.3140	98.3370	98.3590	98.3800	98.4010	98.4210	98.4400	98.4600	98.4800	98.5000	98.5210	98.5410
98.5610	98.5800	98.5990	98.6170	98.6340	98.6520	98.6700	98.6880	98.7060	98.7250	98.7430	98.7600
98.7770	98.7930	98.8090	98.8240	98.8400	98.8560	98.8720	98.8890	98.9050	98.9200	98.9350	98.9490
98.9630	98.9760	98.9900	99.0040	99.0190	99.0330	99.0470	99.0600	99.0730	99.0850	99.0960	99.1080
99.1200	99.1320	99.1440	99.1560	99.1680	99.1800	99.1920	99.2040	99.2170	99.2290	99.2400	99.2510
99.2610	99.2710	99.2800	99.2900	99.3000	99.3100	99.3200	99.3300	99.3400	99.3500	99.3600	99.3700
99.3800	99.3900	99.4000	99.4100	99.4210	99.4310	99.4400	99.4490	99.4570	99.4650	99.4720	99.4800
99.4880	99.4960	99.5040	99.5120	99.5200	99.5280	99.5360	99.5440	99.5520	99.5600	99.5680	99.5760
99.5840	99.5920	99.6000	99.6080	99.6170	99.6250	99.6330	99.6400	99.6470	99.6530	99.6590	99.6640
99.6700	99.6760	99.6820	99.6880	99.6940	99.7000	99.7060	99.7120	99.7180	99.7240	99.7300	99.7360
99.7420	99.7480	99.7540	99.7600	99.7660	99.7720	99.7790	99.7850	99.7900	99.7950	99.7990	99.8020
99.8060	99.8100	99.8140	99.8180	99.8220	99.8260	99.8300	99.8340	99.8380	99.8420	99.8460	99.8500
99.8540	99.8580	99.8620	99.8660	99.8700	99.8740	99.8780	99.8820	99.8860	99.8900	99.8940	99.8980
99.9030	99.9070	99.9100	99.9130	99.9150	99.9160	99.9180	99.9200	99.9220	99.9240	99.9260	99.9280
99.9300	99.9320	99.9340	99.9360	99.9380	99.9400	99.9420	99.9440	99.9460	99.9480	99.9500	99.9520
99.9540	99.9560	99.9580	99.9600	99.9620	99.9640	99.9660	99.9680	99.9700	99.9720	99.9740	99.9760
99.9780	99.9800	99.9820	99.9840	99.9860	99.9880	99.9900	99.9920	99.9940	99.9970	99.9990	100.0000

T_{lag} Equation Source

In the 1971 Walnut Creek Study, the Corps used the April 2, 1958 storm rainfall records and flood hydrograph recorded at the USGS San Ramon Creek at San Ramon gage to derive the unit hydrograph for an un-urbanized watershed. The equation they used for lag time (T_{lag}) is the same as used in the HYDRO6 model and that shown in the training material and other documents. The lag time (in hours) is expressed by the following equation:

$$\mathbf{T_{lag} = 24 \times N \times \left(\frac{L \times L_{ca}}{S^{0.5}}\right)^{0.38}}$$

Where: T_{lag} = Elapsed time from the beginning of an assumed continuous series of unit effective rainfalls over and area to the instant at which the rate of the resulting run-off at the area concentration point equals 50 percent of the maximum (ultimate) rate of the resulting run-off at that point. This therefore corresponds to the Time = 100% and volume = 50%. The S-curve percent time goes to 840% of T_{lag}.

L = length of the main drainage path (miles)

L_{ca} = length along that drainage path from a point opposite[6] the centroid of the watershed to the outlet point (miles)

S = overall slope of the main watercourse (feet/mile),

N = weighted watershed Manning coefficient (dimensionless)

The parameters used in the T_{lag} equation are discussed in more detail in other documents.

[6] Opposite – This term was used by Franklin F. Snyder in his 1938 report to the American Geophysical Union (AGU) titled "Synthetic Unit Graphs". It has been interpreted to mean a point on the main watercourse or channel determined by the perpendicular projection of the centroid to the main watercourse or channel.

APPENDIX A - NRCS 24-Hour Curves

The following rainfall distribution curves were provided by Jim Chapman, P.E. of the USDA-NRCS office at 430 G Street Davis, CA 95616 (530) 792-5612.

They are presented below as they were provided except for the 6-hour curve immediately below. The time increment for the 6-hour curve was revised from 0.02 to 0.12 to make the 50 time increments equal to 6 hours.

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SCS STANDARD RAINFALL DISTRIBUTIONS     REV 6/85

SCS STANDARD RAINFALL DIMENSIONLESS DISTRIBUTION
for 6 hours
EMERGENCY SPILLWAY AND FREEBOARD HYDROGRAPHS
CUMULATIVE RAINFALL TABLE
(REVISED MAY 1982)
Time increment is 0.12 hour, beginning at 0.0 hours
  RAINFL   0.12
     0.0   0.00800.01620.02460.0333
     0.04250.05240.06300.07430.0863
     0.09900.11240.12650.14200.1595
     0.18000.20500.25500.34500.4370
     0.53000.60300.63300.66000.6840
     0.70500.72400.74200.75900.7750
     0.79000.80430.81800.83120.8439
     0.85610.86780.87900.88980.9002
     0.91030.92010.92970.93910.9483
     0.95730.96610.97470.98320.9916
     1.0000
```

SCS STANDARD RAINFALL DISTRIBUTIONS REV 6/85

TYPE I SCS STANDARD RAINFALL DISTRIBUTION for 24 hours

Time increment is 0.1 hour, beginning at 0.0 hours

RAINFL 1 0.1

0.00000	0.00174	0.00348	0.00522	0.00697
0.00871	0.01046	0.01220	0.01395	0.01570
0.01745	0.01920	0.02095	0.02270	0.02446
0.02621	0.02797	0.02972	0.03148	0.03324
0.03500	0.03677	0.03858	0.04041	0.04227
0.04416	0.04608	0.04803	0.05001	0.05201
0.05405	0.05611	0.05821	0.06033	0.06248
0.06466	0.06687	0.06911	0.07138	0.07367
0.07600	0.07835	0.08070	0.08307	0.08545
0.08784	0.09024	0.09265	0.09507	0.09751
0.09995	0.10241	0.10487	0.10735	0.10984
0.11234	0.11485	0.11737	0.11990	0.12245
0.12500	0.12761	0.13034	0.13317	0.13610
0.13915	0.14230	0.14557	0.14894	0.15241
0.15600	0.15966	0.16334	0.16706	0.17082
0.17460	0.17842	0.18226	0.18614	0.19006
0.19400	0.19817	0.20275	0.20775	0.21317
0.21900	0.22523	0.23185	0.23885	0.24623
0.25400	0.26233	0.27139	0.28119	0.29173
0.30300	0.31942	0.34542	0.38784	0.46316
0.51500	0.53220	0.54760	0.56120	0.57300
0.58300	0.59188	0.60032	0.60832	0.61588
0.62300	0.62982	0.63648	0.64298	0.64932
0.65550	0.66152	0.66738	0.67308	0.67862
0.68400	0.68925	0.69440	0.69945	0.70440
0.70925	0.71400	0.71865	0.72320	0.72765
0.73200	0.73625	0.74040	0.74445	0.74840
0.75225	0.75600	0.75965	0.76320	0.76665
0.77000	0.77329	0.77656	0.77981	0.78304
0.78625	0.78944	0.79261	0.79576	0.79889
0.80200	0.80509	0.80816	0.81121	0.81424
0.81725	0.82024	0.82321	0.82616	0.82909
0.83200	0.83489	0.83776	0.84061	0.84344
0.84625	0.84904	0.85181	0.85456	0.85729
0.86000	0.86269	0.86536	0.86801	0.87064
0.87325	0.87584	0.87841	0.88096	0.88349
0.88600	0.88849	0.89096	0.89341	0.89584
0.89825	0.90064	0.90301	0.90536	0.90769
0.91000	0.91229	0.91456	0.91681	0.91904
0.92125	0.92344	0.92561	0.92776	0.92989
0.93200	0.93409	0.93616	0.93821	0.94024
0.94225	0.94424	0.94621	0.94816	0.95009
0.95200	0.95389	0.95576	0.95761	0.95944
0.96125	0.96304	0.96481	0.96656	0.96829
0.97000	0.97169	0.97336	0.97501	0.97664
0.97825	0.97984	0.98141	0.98296	0.98449
0.98600	0.98749	0.98896	0.99041	0.99184
0.99325	0.99464	0.99601	0.99736	0.99869
1.0000				

SCS STANDARD RAINFALL DISTRIBUTIONS REV 6/85

TYPE IA SCS STANDARD RAINFALL DISTRIBUTION for 24 hours

Time increment is 0.1 hour, beginning at 0.0 hours

RAINFL 0.1

0.00000	0.00224	0.00432	0.00628	0.00816
0.01000	0.01184	0.01372	0.01568	0.01776
0.02000	0.02276	0.02568	0.02872	0.03184
0.03500	0.03797	0.04095	0.04394	0.04695
0.05000	0.05315	0.05633	0.05954	0.06276
0.06600	0.06920	0.07240	0.07560	0.07880
0.08200	0.08514	0.08829	0.09147	0.09471
0.09800	0.10147	0.10502	0.10862	0.11229
0.11600	0.11969	0.12342	0.12721	0.13107
0.13500	0.13901	0.14310	0.14729	0.15159
0.15600	0.16059	0.16530	0.17011	0.17501
0.18000	0.18494	0.18999	0.19517	0.20049
0.20600	0.21196	0.21808	0.22432	0.23064
0.23700	0.24285	0.24878	0.25490	0.26127
0.26800	0.27517	0.28287	0.29118	0.30019
0.31000	0.33142	0.35469	0.37876	0.40255
0.42500	0.43936	0.45168	0.46232	0.47164
0.48000	0.48904	0.49752	0.50548	0.51296
0.52000	0.52664	0.53292	0.53888	0.54456
0.55000	0.55564	0.56116	0.56656	0.57184
0.57700	0.58198	0.58685	0.59163	0.59635
0.60100	0.60576	0.61044	0.61504	0.61956
0.62400	0.62836	0.63264	0.63684	0.64096
0.64500	0.64889	0.65272	0.65651	0.66026
0.66400	0.66773	0.67148	0.67527	0.67910
0.68300	0.68665	0.69027	0.69386	0.69744
0.70100	0.70473	0.70838	0.71198	0.71551
0.71900	0.72245	0.72586	0.72926	0.73263
0.73600	0.73939	0.74277	0.74613	0.74948
0.75281	0.75613	0.75943	0.76271	0.76598
0.76924	0.77248	0.77571	0.77892	0.78211
0.78529	0.78845	0.79160	0.79474	0.79786
0.80096	0.80405	0.80712	0.81018	0.81322
0.81625	0.81926	0.82226	0.82524	0.82821
0.83116	0.83410	0.83702	0.83992	0.84281
0.84569	0.84855	0.85140	0.85423	0.85704
0.85984	0.86262	0.86539	0.86815	0.87089
0.87361	0.87632	0.87901	0.88169	0.88435
0.88700	0.88963	0.89225	0.89485	0.89744
0.90001	0.90257	0.90511	0.90763	0.91014
0.91264	0.91512	0.91759	0.92004	0.92247
0.92489	0.92729	0.92968	0.93206	0.93442
0.93676	0.93909	0.94140	0.94370	0.94598
0.94825	0.95050	0.95274	0.95496	0.95717
0.95936	0.96154	0.96370	0.96584	0.96797
0.97009	0.97219	0.97428	0.97635	0.97840
0.98044	0.98246	0.98447	0.98647	0.98845
0.99041	0.99236	0.99429	0.99621	0.99811
1.0000				

TYPE II SCS STANDARD RAINFALL DISTRIBUTION for 24 hours REV 6/85

Time increment is 0.1 hour, beginning at 0.0 hours

0.00000	0.00101	0.00202	0.00305	0.00408
0.00513	0.00618	0.00725	0.00832	0.00941
0.01050	0.01161	0.01272	0.01385	0.01498
0.01613	0.01728	0.01845	0.01962	0.02081
0.02200	0.02321	0.02442	0.02565	0.02688
0.02813	0.02938	0.03065	0.03192	0.03321
0.03450	0.03581	0.03712	0.03845	0.03978
0.04113	0.04248	0.04385	0.04522	0.04661
0.04800	0.04941	0.05084	0.05229	0.05376
0.05525	0.05676	0.05829	0.05984	0.06141
0.06300	0.06461	0.06624	0.06789	0.06956
0.07125	0.07296	0.07469	0.07644	0.07821
0.08000	0.08181	0.08364	0.08549	0.08736
0.08925	0.09116	0.09309	0.09504	0.09701
0.09900	0.10101	0.10304	0.10509	0.10716
0.10925	0.11136	0.11349	0.11564	0.11781
0.12000	0.12225	0.12460	0.12705	0.12960
0.13225	0.13500	0.13785	0.14080	0.14385
0.14700	0.15020	0.15340	0.15660	0.15980
0.16300	0.16628	0.16972	0.17332	0.17708
0.18100	0.18512	0.18948	0.19408	0.19892
0.20400	0.20940	0.21520	0.22140	0.22800
0.23500	0.24268	0.25132	0.26092	0.27148
0.28300	0.30684	0.35436	0.43079	0.56786
0.66300	0.68196	0.69864	0.71304	0.72516
0.73500	0.74344	0.75136	0.75876	0.76564
0.77200	0.77796	0.78364	0.78904	0.79416
0.79900	0.80360	0.80800	0.81220	0.81620
0.82000	0.82367	0.82726	0.83079	0.83424
0.83763	0.84094	0.84419	0.84736	0.85047
0.85350	0.85647	0.85936	0.86219	0.86494
0.86763	0.87024	0.87279	0.87526	0.87767
0.88000	0.88229	0.88455	0.88679	0.88900
0.89119	0.89335	0.89549	0.89760	0.89969
0.90175	0.90379	0.90580	0.90779	0.90975
0.91169	0.91360	0.91549	0.91735	0.91919
0.92100	0.92279	0.92455	0.92629	0.92800
0.92969	0.93135	0.93299	0.93460	0.93619
0.93775	0.93929	0.94080	0.94229	0.94375
0.94519	0.94660	0.94799	0.94935	0.95069
0.95200	0.95330	0.95459	0.95588	0.95716
0.95844	0.95971	0.96098	0.96224	0.96350
0.96475	0.96600	0.96724	0.96848	0.96971
0.97094	0.97216	0.97338	0.97459	0.97580
0.97700	0.97820	0.97939	0.98058	0.98176
0.98294	0.98411	0.98528	0.98644	0.98760
0.98875	0.98990	0.99104	0.99218	0.99331
0.99444	0.99556	0.99668	0.99779	0.99890
1.0000				

SCS STANDARD RAINFALL DISTRIBUTIONS REV 6/85

TYPE III SCS STANDARD RAINFALL DISTRIBUTION for 24 hours

Time increment is 0.1 hour, beginning at 0.0 hours

RAINFL 0.1

0.00000	0.00100	0.00200	0.00300	0.00400
0.00500	0.00600	0.00700	0.00800	0.00900
0.01000	0.01100	0.01200	0.01300	0.01400
0.01500	0.01600	0.01700	0.01800	0.01900
0.02000	0.02101	0.02203	0.02307	0.02412
0.02519	0.02627	0.02737	0.02848	0.02961
0.03075	0.03191	0.03308	0.03427	0.03547
0.03669	0.03792	0.03917	0.04043	0.04171
0.04300	0.04431	0.04563	0.04697	0.04832
0.04969	0.05107	0.05247	0.05388	0.05531
0.05675	0.05821	0.05968	0.06117	0.06267
0.06419	0.06572	0.06727	0.06883	0.07041
0.07200	0.07363	0.07530	0.07703	0.07880
0.08063	0.08250	0.08443	0.08640	0.08843
0.09050	0.09263	0.09480	0.09703	0.09930
0.10163	0.10400	0.10643	0.10890	0.11143
0.11400	0.11666	0.11943	0.12232	0.12532
0.12844	0.13167	0.13502	0.13848	0.14206
0.14575	0.14956	0.15348	0.15752	0.16167
0.16594	0.17032	0.17482	0.17943	0.18416
0.18900	0.19402	0.19928	0.20478	0.21052
0.21650	0.22272	0.22918	0.23588	0.24282
0.25000	0.25776	0.26644	0.27604	0.28656
0.29800	0.31430	0.33940	0.37330	0.41600
0.50000	0.58400	0.62670	0.66060	0.68570
0.70200	0.71344	0.72396	0.73356	0.74224
0.75000	0.75718	0.76412	0.77082	0.77728
0.78350	0.78948	0.79522	0.80072	0.80598
0.81100	0.81584	0.82057	0.82518	0.82968
0.83406	0.83833	0.84248	0.84652	0.85044
0.85425	0.85794	0.86152	0.86498	0.86833
0.87156	0.87468	0.87768	0.88057	0.88334
0.88600	0.88858	0.89110	0.89358	0.89600
0.89838	0.90070	0.90298	0.90520	0.90738
0.90950	0.91158	0.91360	0.91558	0.91750
0.91938	0.92120	0.92298	0.92470	0.92638
0.92800	0.92959	0.93117	0.93273	0.93428
0.93581	0.93733	0.93883	0.94032	0.94179
0.94325	0.94469	0.94612	0.94753	0.94893
0.95031	0.95168	0.95303	0.95437	0.95569
0.95700	0.95829	0.95958	0.96085	0.96211
0.96336	0.96460	0.96582	0.96704	0.96824
0.96944	0.97062	0.97179	0.97295	0.97410
0.97523	0.97636	0.97747	0.97858	0.97967
0.98075	0.98182	0.98288	0.98392	0.98496
0.98598	0.98700	0.98800	0.98899	0.98997
0.99094	0.99189	0.99284	0.99377	0.99470
0.99561	0.99651	0.99740	0.99828	0.99914
1.0000				